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(54) **METHOD AND SYSTEM FOR ALIGNING PROPULSION SYSTEM AND VEHICLE HAVING SUCH PROPULSION ALIGNMENT**

VERFAHREN UND SYSTEM ZUR AUSRICHTUNG EINES ANTRIEBSSYSTEMS UND FAHRZEUG
MIT EINER DERARTIGEN ANTRIEBSAUSRICHTUNG

PROCÉDÉ ET SYSTÈME D'ALIGNEMENT DE SYSTÈME DE PROPULSION ET VÉHICULE AYANT
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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority under 35 U.S.C. 119(e) of United States Provisional Patent Application No. 62/168,342 filed on May 29, 2015.

TECHNICAL FIELD

[0002] The invention relates to vehicles and, more particularly, to a method and system for aligning a propulsion system on an aerospace vehicle with respect to a direction of thrust, and an aerospace vehicle having such aligned propulsion system.

BACKGROUND

[0003] A force propulsion mechanism is typically designed and assembled onto a vehicle based upon alignment of a centerline of the mechanism with respect to a reference axis of the vehicle. For example, a civilian commercial aircraft typically includes turbofan engines disposed within a nacelle housing, mounted upon a pylon under wing or at another location on the aircraft. The turbofan engine includes a nose cone at a forward location and a tail cone at a rearward location. Traditionally, an engine centerline axis is calculated as extending from a centrally positioned point on the nose cone through a centrally positioned point on the tail cone. This centerline axis is then used to design the mounting orientation of the engine upon the aircraft. That is, in the design phase, the location and orientation of the turbofan engine on the aircraft is determined by utilizing the engine centerline with reference to a symmetry axis of the aircraft such as a top level aircraft axis. After the turbofan engine is assembled and mounted on the aircraft, engine symmetry is measured exclusively with respect to the engine centerline axis.

[0004] However, the engine centerline axis does not always align with the thrust vector axis of the respective engine, i.e., an axis which extends longitudinally through the majority of thrust emitted from the engine. In fact, often the engine centerline axis and the thrust vector axis do not coincide and are instead divergent. As a result, engine thrust is not properly aligned with its designed direction with respect to the aircraft. This misalignment leads to a drag penalty that impacts, among other things, the high-speed performance of the aircraft. Furthermore, directional thrust misalignment can result in unintended and unexpected increases in fuel consumption, thus contributing to an overall reduction in aircraft efficiency. These disadvantages are particularly evident with high bypass ratio turbofan engines in which a majority of thrust is provided from the bypass core as compared with thrust provided directly from the engine via the tail cone. The significant thrust emitted from the bypass core is often not aligned with the engine centerline axis. Thus, relying

on the centerline axis as the only parameter for establishing engine position on the aircraft results in inevitable misalignment and hence contributes to performance reductions.

[0005] Thus, a method and a system is required which reduce misalignment between engine thrust and the desired aircraft direction of travel, while reducing the time, costs, and complexity of completing engine symmetry checks.

[0006] Examples of prior art systems can be found in US 2010 212 288 A1 (SUCHEZKY), which describes a method of adjusting the exhaust gas flow direction; US 3 480 236 A (NASH DUDLEY O), which describes a system to adjust the direction of thrust produced by the engine; and US 8 322 655 B1 (KISMARTON MAX), which describes a system for aircraft production and service methodology.

BRIEF SUMMARY

[0007] The invention is set out in the appended set of claims 1-6.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The various embodiments of the present disclosure can be understood with reference to the following drawings. The components are not necessarily to scale. Also, in the drawings, like reference numerals designate corresponding parts throughout the several views.

Figure 1 shows an aircraft in one embodiment of the disclosure;

Figure 2 illustrates a turbofan engine of the aircraft of Figure 1;

Figure 3 is a rear perspective view of the engine of Figure 2;

Figure 4 is a partial side view of the aircraft of Figure 1;

Figure 5 is a partial top view of the aircraft of Figure 1;

Figure 6 is a flow diagram showing a method of aligning and mounting an engine on an aircraft; and

Figure 7 is a flow diagram showing an exemplary for method determining a thrust vector of a turbofan engine.

DETAILED DESCRIPTION

[0009] The present disclosure is more particularly described in the following description and examples that are intended to be illustrative only since numerous modifications and variations therein will be apparent to those

skilled in the art. As used in the specification and in the claims, the singular form "a," "an," and "the" may include plural referents unless the context clearly dictates otherwise. Also, as used in the specification and in the claims, the term "comprising" may include the embodiments "consisting of" and "consisting essentially of." Furthermore, all ranges disclosed herein are inclusive of the endpoints and are independently combinable.

[0010] As used herein, approximating language may be applied to modify any quantitative representation that may vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "about" and "substantially," may not be limited to the precise value specified, in some cases. In at least some instances, the approximating language may correspond to the precision of calculating and/or storing the value.

[0011] Figure 1 shows a civilian commercial jetliner 10 including a fuselage 12 having a right wing 14 and a left wing 16 with a right engine 18 disposed beneath the right wing 14 and a left engine 20 disposed beneath the left wing 16. In this illustrative example, the engines 18, 20 are high bypass turbofan engines. The aircraft 10 is assigned a centerline reference axis 22, which extends through the fuselage 12, and an orthogonal reference axis 24, which extends perpendicular to the centerline reference axis 22. The aircraft 10 further includes a datum MC axis 25 which extends along a side of the aircraft 10.

[0012] Figures 2 and 3 provide enlarged, partial views of the aircraft of Figure 1, specifically showing the right turbofan engine 18 mounted on a pylon 26 beneath the right wing 14. The engine 18 comprises an engine core 28 having a nose cone 30 disposed at a forward end of the engine 18 and a tail cone 32 arranged at a rearward, aft end of the engine 18. A nacelle 33 surrounds the engine core 28 and, in this example, includes opposing cowls 34 and 36 arranged in a clamshell fashion about the engine core 28. Such a clamshell arrangement may consist of a hinged coupling between the cowls 34, 36 and the pylon 26 with a mechanical connection between the cowls 34, 36 at an end opposite from the pylon 26. This construction is of course exemplary and may vary as desired within the scope of the appended claims.

[0013] For example, a single cowl may form the nacelle 33, or more than two cowls can be used to construct the nacelle 33. However, for illustrative purposes, the nacelle 33 will herein be described as comprising two cowls 34 and 36.

[0014] The turbofan engine 18 includes an exit plane 38 located at the rearward aft end.

[0015] The exit plane 38 is delimited by a rearward edge 40 of the nacelle cowls 34, 36. An engine thrust vector feature 43 is defined in relation to the exit plane 38.

[0016] The thrust vector feature 43 is a reference axis 42 which is defined as an axis extending perpendicularly and generally centrally from the exit plane 38 of the turbofan engine 18. This reference axis 42 may be collinear with an actual thrust vector axis of the engine 18 or it may

extend at an angle thereto. The thrust vector axis is an axis which extends rearward of the engine 18, longitudinally through the majority of thrust emitted by the engine 18.

[0017] In an example not within the scope of the appended claims, the thrust vector feature 43 may comprise the exit plane 38. More generally, the thrust vector feature may be any geometric element associated with the propulsion force emitted by the engine and which is used to orient the engine relative to the rest of the aircraft.

[0018] The exit plane 38 is established by identifying a plurality of points 44, 46 located at the rearward edge 40 of the nacelle cowls 34, 36. For example, and as best shown in Figure 3, points 44a, 44b, 44c, 44d, and 44e are located on the cowl 34 while points 46a, 46b, 46c, 46d, and 46e are found on the cowl 36. In the illustrated example, points 44a, 44b, 44c, 44d, and 44e are equally spaced with respect to each other. Similarly, points 46a, 46b, 46c, 46d, and 46e are equally spaced along the cowl 36. The exit plane 38 is defined as the least square plane extending amongst the points 44 and 46. Here, the thrust vector feature 43 is defined as a reference axis 42 (which could be a thrust vector axis) extending perpendicular to this least square plane 38. The selected points 44, 46 are of course merely exemplary, any plurality of points at the rear of the engines 18, 20 may be used to determine the exit plane 38, and such points may be equally or unequally spaced. The points 46, 48 used to establish the exit plane 38 can be calculated by any sufficient means and by use of any sufficient mechanism. In one example, a laser tracker is used to locate various points at the rear of the nacelle cowls. Here, the laser tracker is brought into contact with the cowls at specific locations and computer software and a server locate the points in a three dimensional coordinate reference system and determine the plane extending there between. Then this system establishes the thrust vector feature 43 and is configured to compare the same to the symmetry axes of the aircraft.

[0019] During the design phase of the aircraft 10, the thrust vector feature 43 is related to one or more of the various aircraft reference axes in order to determine position and orientation and possible variation of the engines 18, 20. For example, as shown in Figure 4, the exit plane 38 can be projected onto the aircraft centerline axis 22 and/or onto a wing symmetry axis 23. The angles 48 and 50 which extend, respectively, between the projected exit plane 38 and the centerline axis 22 and between the exit plane 38 and the wing symmetry axis 23 are calculated and used for determining a desired vertical position and orientation of the particular engine. Similarly, as shown in Figure 5, the exit plane 38 is projected on the datum MC reference axis 25 and the angle 51 therebetween is used to determine a desired horizontal positioning of the engine, i.e., left-right. Subsequently, these angles are measured after the aircraft is built to confirm the true position of the thrust vector feature 43.

[0020] Thus, the aircraft 10 is designed and assembled

with the turbofan engines 18, 20 mounted upon the wings 14, 16 such that the thrust vector feature 43 of each engine is positioned with respect to the relevant aircraft axes in order to achieve desired drag and fuel efficiency characteristics. The thrust vector feature 43 can coincide with and be aligned with an engine centerline axis 56 which, as seen in Figure 3, extends through the engine core 28 from a point on the nose cone 28 to a point on the tail cone 30. However, due to component variation during build, the thrust vector feature 43 extends independently of and diverges from the engine centerline axis 56. Also, as mentioned previously, the thrust vector feature 43 diverges from the actual thrust vector axis of the engine, i.e., the axis of the majority of thrust emitted by the engine.

[0021] Figure 6 illustrates an exemplary method of determining position and alignment of a high bypass turbofan engine on an aircraft. At a first step 60, a reference axis is determined for the aircraft. As discussed with respect to Figure 1, such reference axis may comprise a centerline axis measured through the fuselage, from a point at the front of the aircraft to a point at the rear. Additionally and/or alternatively, such reference axis may extend orthogonally with respect to the longitudinal axis of the fuselage (see element 24 in Fig. 1) or may be established as a datum MC axis 25, as seen in Figures 1 and 5. Other aircraft reference axes may also be used without departing from the scope of the appended claims.

[0022] Step 62 in Figure 6 concerns the establishment of a thrust vector feature 43 with respect to the turbofan engine. One method of determining such thrust vector feature 43 comprises determining an exit plane of the engine. This exit plane may act as thrust vector feature 43, in an example not within the scope of the appended claims.

[0023] The thrust vector feature 43 is calculated to be an axis perpendicular to the exit plane.

[0024] The thrust vector feature 43 is understood generally to be any geometric feature from which an actual thrust direction of the engine can be determined. Thus, in an alternate embodiment, step 62 involves merely calculating the exit plane and in an example not within the scope of the appended claims, using that as the thrust vector feature.

[0025] Step 64 of Figure 6 involves determining the positioning and orientation of the engine based upon the relationship of the aircraft reference axis and the thrust vector feature 43. Step 64 typically happens during the design phase of an aircraft. Here, the thrust vector feature may be considered and manipulated with direct reference to the aircraft axis. That is, the axis perpendicular to the exit plane may be aligned with or may be arranged diverging from the selected aircraft axis. Alternatively, the exit plane can be projected on to the reference axis. Then the angle between the two axes can be measured and adjusted as necessary to bring the turbofan engines 18, 20 into a desired mounted position. A design that will allow such an adjustment to occur during the engine installation is useful for optimum results but is not neces-

sary for this process to work. At step 66 the engine is mounted upon the aircraft based upon the location information generated in steps 60-64. Optionally, a symmetry check is conducted at step 68 after assembly of the aircraft is completed. Here, symmetry of the engines is determined by comparing the thrust vector feature, i.e., the axis perpendicular to the exit plane and/or the projection of the exit plane, with respect to one or more of the reference engine axes. A similar symmetry check can be conducted after a triggering event, such as a hard landing.

[0026] Figure 7 provides one exemplary method for determining the exit plane of the turbofan engine. At step 70, this is accomplished by identifying a plurality of points at the rear of the engine and using these points to delimit a plane. More specifically, a plurality of equally spaced points, for example 10 points, are located at the rearward terminal edge of cowls of a nacelle which surrounds the core of the turbo fan engine. Then, at step 72, the least square plane is calculated amongst the identified points. Finally, at step 74, the thrust vector feature is calculated, which may be as extending perpendicularly to and rearward from the exit plane. Alternatively, in an example not within the scope of the appended claims, the thrust vector feature is defined as the exit plane itself, or as any geometric feature that is representative of a thrust direction of the engine. The plurality of points used to establish the exit plane may be determined by any suitable means and/or mechanisms. For example, a laser tracker may be brought into contact with the nacelle cowls at specific locations and certain software and servers are then utilized to establish these points in a coordinate reference system and to calculate the plane extending there between.

[0027] The method described herein provide for determination of the thrust vector feature of a turbofan engine and the mounting of such engine upon an aircraft based upon this thrust vector feature, without strictly relying on the centerline of the engine mounting. As a result, the engine is arranged on the aircraft so as to generally align engine thrust with its designed position in relation to one or more aircraft reference axes, thus increasing fuel efficiency and overall performance.

[0028] Herein, the turbofan engines 18, 20 of the aircraft 10 are described as being disposed beneath the respective wings 14, 16. However, this is merely exemplary. The turbofan engines may be disposed elsewhere on the aircraft, for example on the fuselage or at the tail of the aircraft. Similarly, two engines 18, 20 are discussed herein, but of course the scope of the invention covers a single turbofan engine and more than two of such engines, insofar as they fall within the scope of the appended claims.

[0029] Moreover, while the above disclosure describes the engines 18, 20 as being high bypass turbofan engines, in another embodiment they may be low bypass turbofan engines or any other suitable propulsion mechanism sufficient for directing movement of the aircraft.

[0030] Herein, the thrust vector feature is determined by establishing an axis perpendicular to an exit plane of the turbofan engines 18, 20. In an example not within the scope of the appended claims, the thrust vector feature may be defined as an axis which is at an angle to the exit plane of less than or greater than ninety degrees. Alternatively, in an example not within the scope of the appended claims, the thrust vector feature may be calculated by any other method sufficient for determining the primary direction of thrust produced by a particular engine. It is this primary direction of thrust, or a component thereof, which is used to align the engine upon the aircraft. Still further alternatively, in an example not within the scope of the appended claims, the exit plane itself may be used as the thrust vector feature and a projection thereof can be used to calculate orientation of the engine relative the aircraft axis.

[0031] Herein, the invention is described by way of example with reference to an aircraft having a propulsion system.

Claims

1. A method of establishing and varying alignment of a propulsion system on an aircraft (10), the propulsion system comprising a turbofan engine (18) and a nacelle (33) disposed at least partially over the turbofan engine (18), the method comprising:

determining a reference axis (22) of the aircraft (10), by identifying a symmetry axis extending generally longitudinally through a fuselage of the aircraft (10);
determining a thrust vector feature (43) of the propulsion system, wherein determining the thrust vector feature (43) comprises, delimiting an exit plane (38) at a rearward terminal end of the nacelle (33), and defining the thrust vector feature (43) as an axis perpendicular to the exit plane (38), wherein the thrust vector feature (43) is divergent from a centreline axis of the engine; and
aligning the propulsion system horizontally and/or vertically with respect to the aircraft (10) by arranging the thrust vector feature (43) relative to the reference axis (22) of the aircraft (10).

2. The method of claim 1, wherein delimiting said exit plane (38) further comprises identifying a first plurality of points (44, 46) on a rearward terminal surface of a first cowl (34) of the nacelle (33) and identifying a second plurality of points (44, 46) on a rearward terminal surface of a second cowl (36) of the nacelle (33) and identifying a least square plane (38) delimited by the first and second plurality of points (44, 46).

3. The method of claim 1, further comprising: confirm-

ing alignment of the propulsion system including:

measuring a plurality of points (44, 46) at the rearward terminal end of the nacelle (33),
establishing a least square plane (38) defined by said points,
projecting the plane (38) to the reference axis (22), and
comparing the orientation of the exit plane (38) projection with the reference axis (22).

4. The method of claim 1, further comprising: calculating a possible variation of the thrust vector feature (43) relative to the reference axis (22) of the aircraft (10) due to a variation of various aircraft components; and
adapting the design to account for such variations.

5. The method of claim 1, wherein said determining the reference axis (22) of the aircraft (10) comprises identifying a wing symmetry axis (23) which extends relative to a wing of the aircraft (10).

6. The method of claim 1, wherein delimiting said exit plane (38) further comprises assigning at least three points at the rearward terminal end of the nacelle (33) extending over the turbofan engine (18), and extending a plane between said points.

Patentansprüche

1. Verfahren zum Festlegen und Variieren der Ausrichtung eines Antriebssystems an einem Flugzeug (10), wobei das Antriebssystem ein Mantelstromtriebwerk (18) und eine mindestens teilweise über dem Mantelstromtriebwerk (18) angeordnete Gondel (33) umfasst, wobei das Verfahren Folgendes umfasst:

Bestimmen einer Referenzachse (22) des Flugzeugs (10) durch Identifizieren einer Symmetrieachse, die sich im Allgemeinen längs durch einen Rumpf des Flugzeugs (10) erstreckt;
Bestimmen eines Schubvektormerkmals (43) des Antriebssystems, wobei das Bestimmen des Schubvektormerkmals (43) Begrenzen einer Austrittsebene (38) an einem hinteren Abschlussende der Gondel (33) und Definieren des Schubvektormerkmals (43) als eine Achse senkrecht zu der Austrittsebene (38) umfasst, wobei das Schubvektormerkmal (43) von einer Mittellinienachse des Triebwerks abweicht; und
Ausrichten des Antriebssystems horizontal und/oder vertikal in Bezug auf das Flugzeug (10) durch Anordnen des Schubvektormerkmals (43) relativ zu der Referenzachse (22) des Flugzeugs (10).

2. Verfahren nach Anspruch 1, wobei das Begrenzen der Austrittsebene (38) ferner Identifizieren einer ersten Vielzahl von Punkten (44, 46) auf einer hinteren Abschlussoberfläche einer ersten Motorhaube (34) der Gondel (33) und Identifizieren einer zweiten Vielzahl von Punkten (44, 46) auf einer hinteren Abschlussoberfläche einer zweiten Motorhaube (36) der Gondel (33) und Identifizieren einer Ebene (38) kleinster Quadrate, die durch die erste und die zweite Vielzahl von Punkten (44, 46) begrenzt ist, umfasst. 5 10
3. Verfahren nach Anspruch 1, ferner umfassend: Bestätigen der Ausrichtung des Antriebssystems, einschließend: 15
 - Messen einer Vielzahl von Punkten (44, 46) an dem hinteren Abschlussende der Gondel (33), Festlegen einer Ebene (38) kleinster Quadrate, die durch die Punkte definiert ist, Projizieren der Ebene (38) auf die Referenzachse (22) und 20
 - Vergleichen der Orientierung der Projektion der Austrittsebene (38) mit der Referenzachse (22).
4. Verfahren nach Anspruch 1, ferner umfassend: Berechnen einer möglichen Variation des Schubvektormerkmal (43) relativ zu der Referenzachse (22) des Flugzeugs (10) aufgrund einer Variation verschiedener Flugzeugkomponenten; und 25
- Anpassen der Ausgestaltung, um solchen Variationen Rechnung zu tragen. 30
5. Verfahren nach Anspruch 1, wobei das Bestimmen der Referenzachse (22) des Flugzeugs (10) Identifizieren einer Tragflächensymmetrieachse (23) umfasst, die sich relativ zu einer Tragfläche des Flugzeugs (10) erstreckt. 35
6. Verfahren nach Anspruch 1, wobei das Begrenzen der Austrittsebene (38) ferner Zuweisen von mindestens drei Punkten an dem hinteren Abschlussende der Gondel (33), das sich über das Mantelstromtriebwerk (18) erstreckt, und Erstrecken einer Ebene zwischen den Punkten umfasst. 40

Revendications

1. Procédé d'établissement et de variation d'alignement d'un système de propulsion sur un aéronef (10), le système de propulsion comprenant un moteur à turboréacteur à double flux (18) et une nacelle (33) disposée au moins partiellement sur le moteur à turboréacteur à double flux (18), le procédé comprenant : 50
 - la détermination d'un axe de référence (22) de l'aéronef (10), en identifiant un axe de symétrie 55

s'étendant globalement de manière longitudinale à travers un fuselage de l'aéronef (10) ; la détermination d'un élément de vecteur de poussée (43) du système de propulsion, ladite détermination de l'élément de vecteur de poussée (43) comprenant la délimitation d'un plan de sortie (38) au niveau d'une extrémité terminale arrière de la nacelle (33), et la définition de l'élément de vecteur de poussée (43) sous la forme d'un axe perpendiculaire au plan de sortie (38), ledit élément de vecteur de poussée (43) étant divergent d'un axe central du moteur ; et l'alignement du système de propulsion horizontalement et/ou verticalement par rapport à l'aéronef (10) en agençant l'élément de vecteur de poussée (43) par rapport à l'axe de référence (22) de l'aéronef (10).

2. Procédé de la revendication 1, ladite délimitation du dit plan de sortie (38) comprenant en outre l'identification d'une première pluralité de points (44, 46) sur une surface terminale arrière d'un premier capot (34) de la nacelle (33) et l'identification d'une seconde pluralité de points (44, 46) sur une surface terminale arrière d'un second capot (36) de la nacelle (33) et l'identification d'un plan des moindres carrés (38) délimité par la première et la seconde pluralité de points (44, 46).
3. Procédé de la revendication 1, comprenant en outre : la confirmation de l'alignement du système de propulsion comprenant :
 - la mesure d'une pluralité de points (44, 46) au niveau de l'extrémité terminale arrière de la nacelle (33), l'établissement d'un plan des moindres carrés (38) défini par lesdits points, la projection du plan (38) sur l'axe de référence (22), et la comparaison de l'orientation de la projection du plan de sortie (38) avec l'axe de référence (22).
4. Procédé de la revendication 1, comprenant en outre : le calcul d'une variation possible de l'élément de vecteur de poussée (43) par rapport à l'axe de référence (22) de l'aéronef (10) en raison d'une variation de divers composants de l'aéronef ; et l'adaptation de la conception pour tenir compte de ces variations.
5. Procédé de la revendication 1, ladite détermination de l'axe de référence (22) de l'aéronef (10) comprenant l'identification d'un axe de symétrie (23) d'aile qui s'étend par rapport à une aile de l'aéronef (10).

6. Procédé de la revendication 1, ladite délimitation du-dit plan de sortie (38) comprenant en outre l'attribution d'au moins trois points au niveau de l'extrémité terminale arrière de la nacelle (33) s'étendant sur le moteur à turboréacteur à double flux (18), et l'extension d'un plan entre lesdits points.

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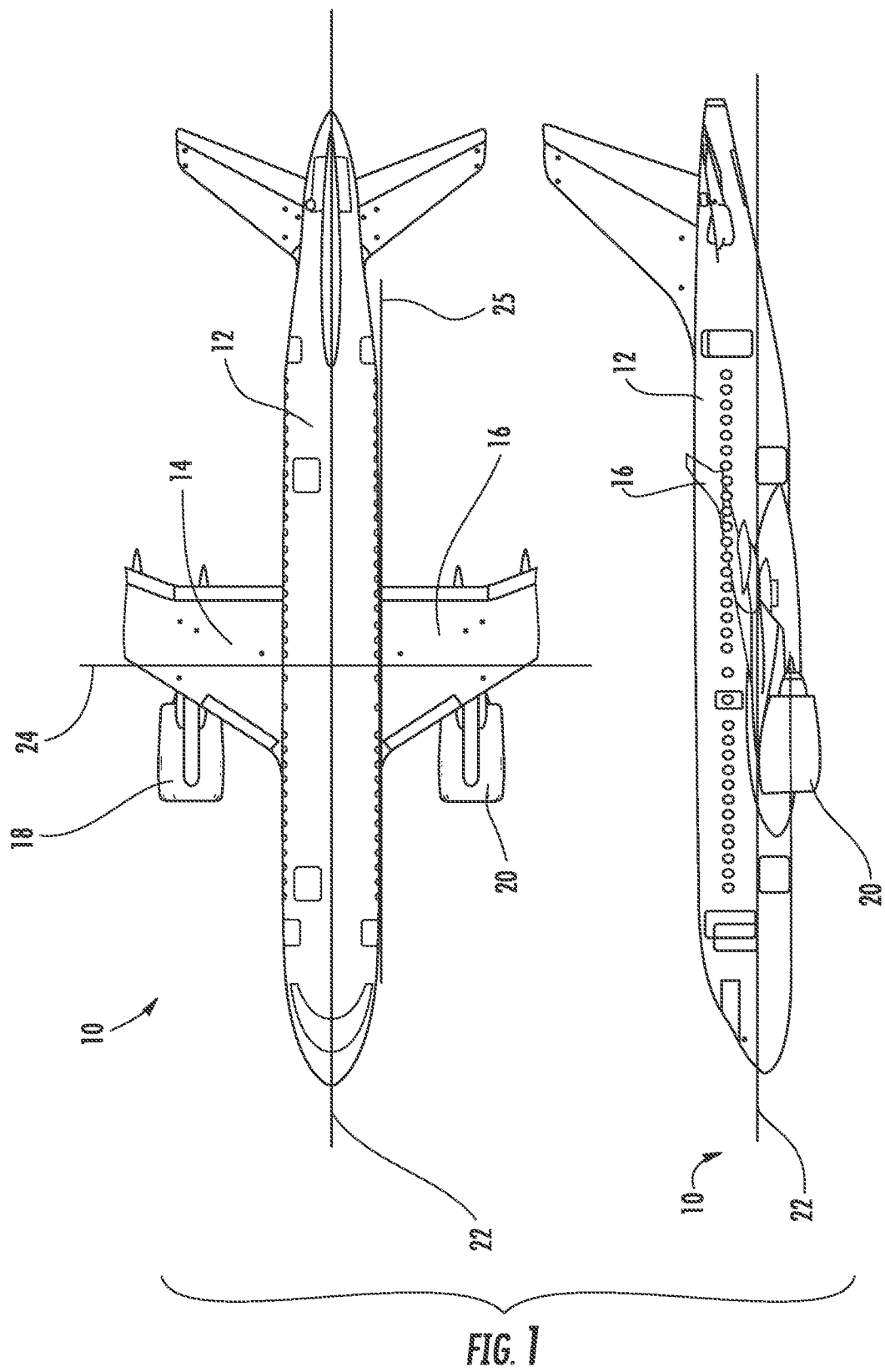
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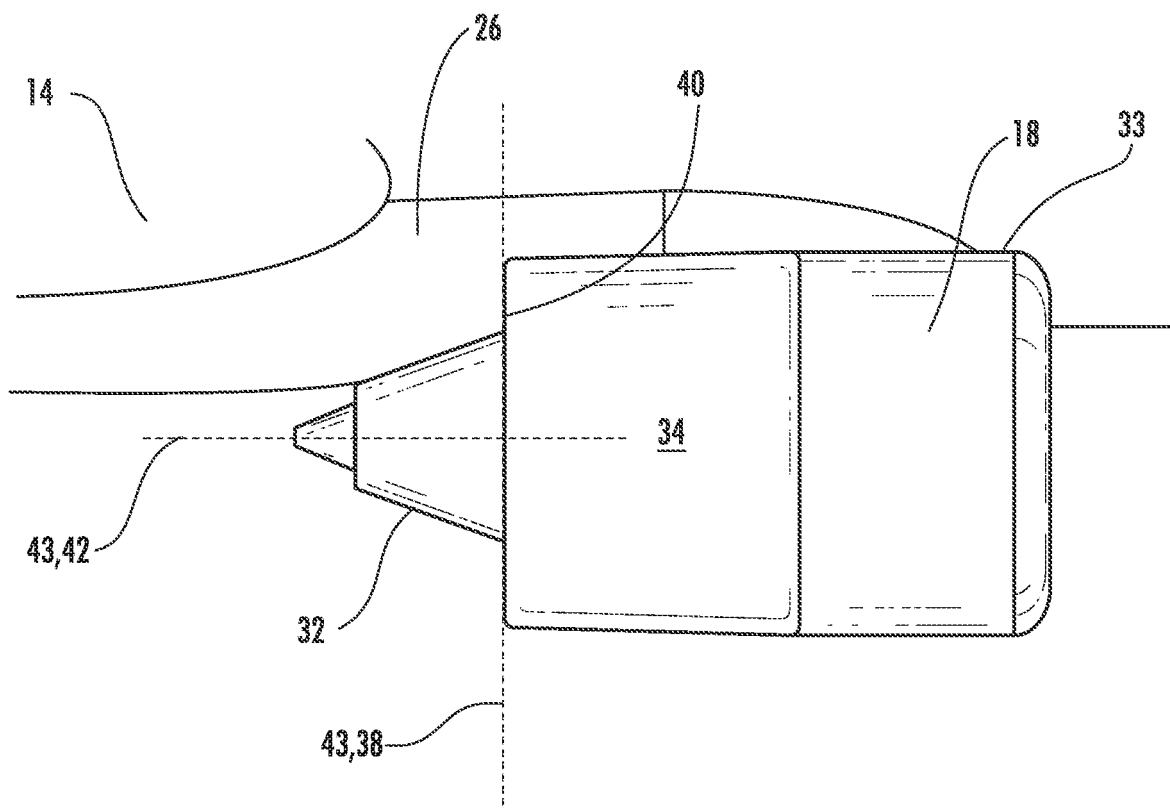
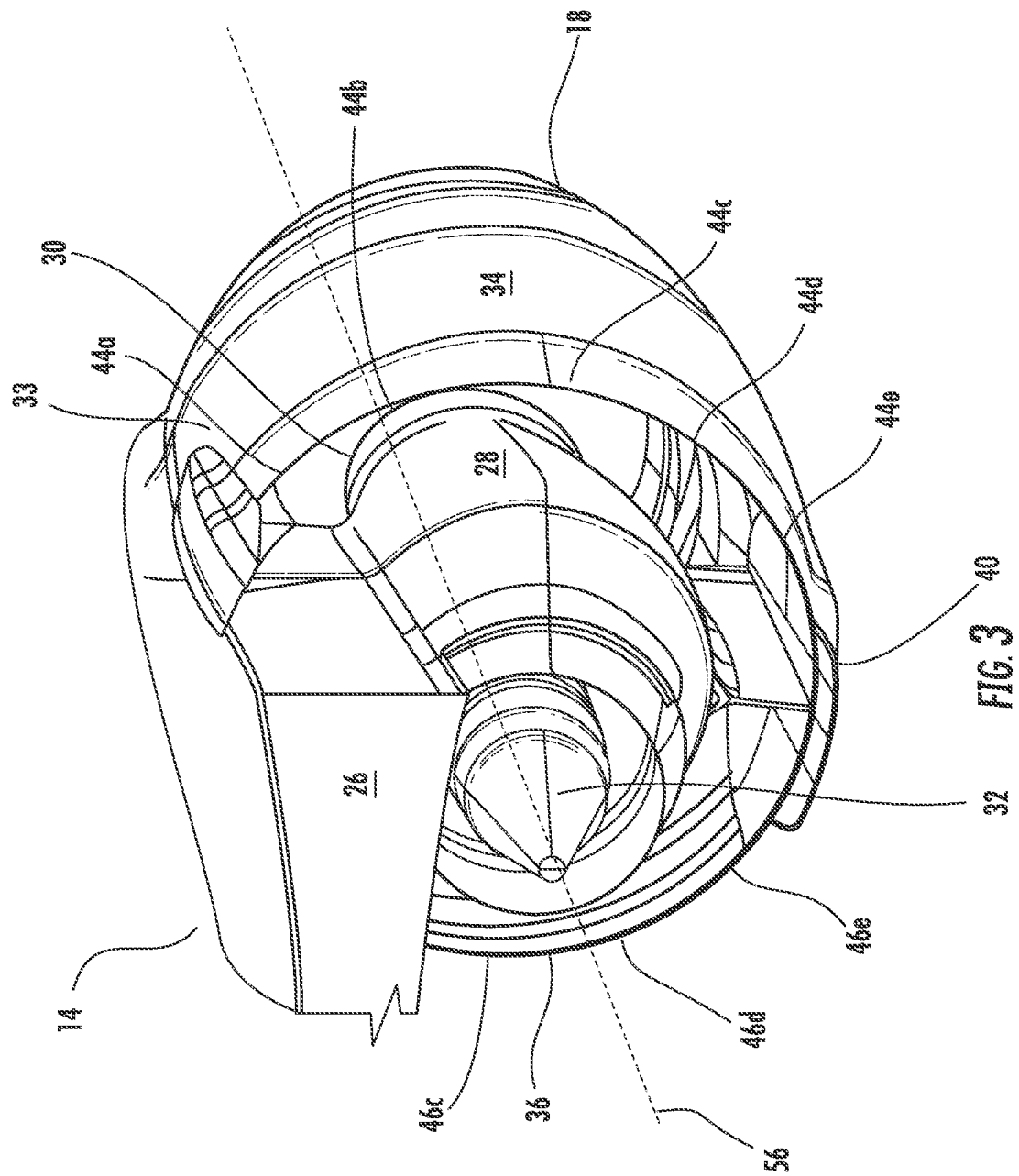


FIG. 2



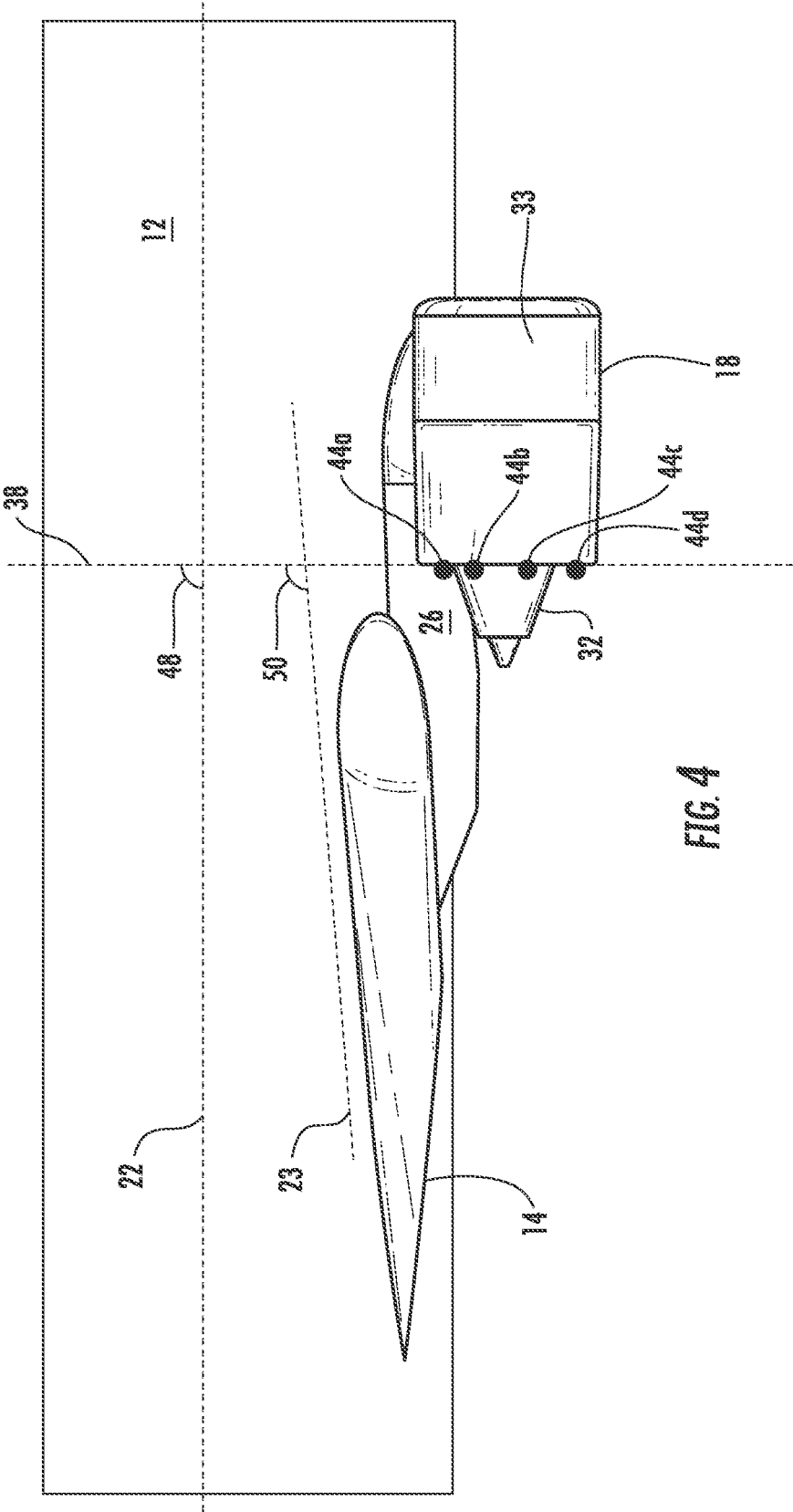


FIG. 4

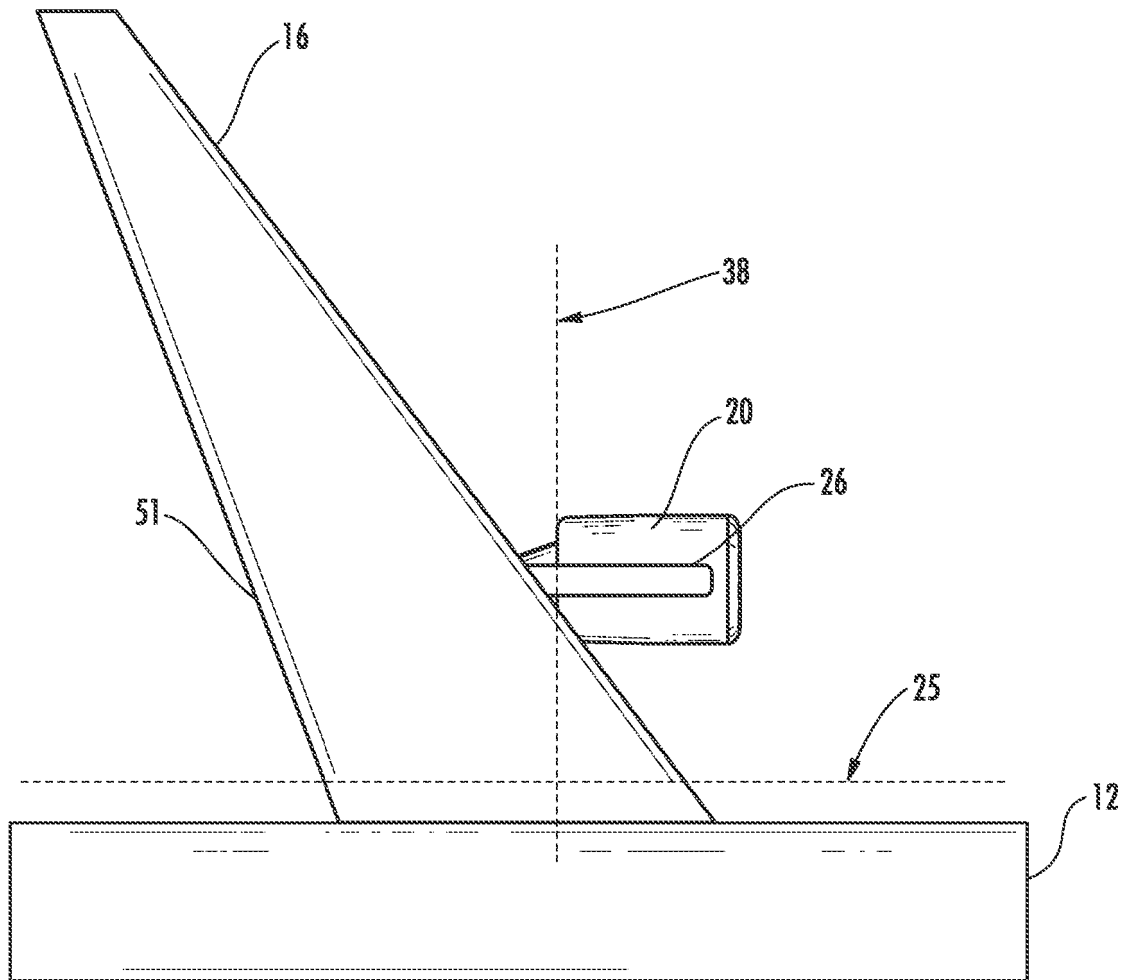


FIG. 5

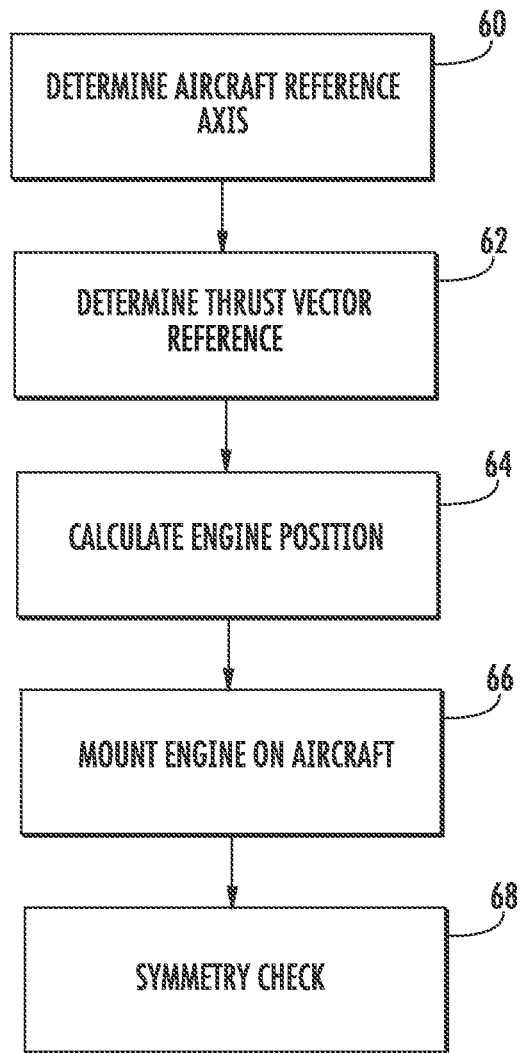


FIG. 6

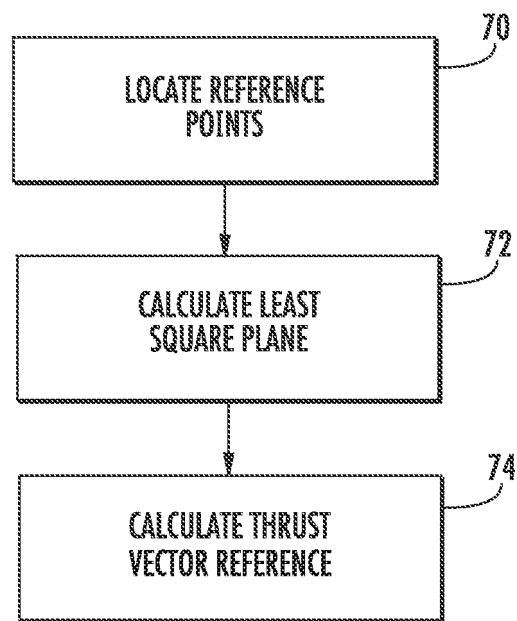


FIG. 7

REFERENCES CITED IN THE DESCRIPTION

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